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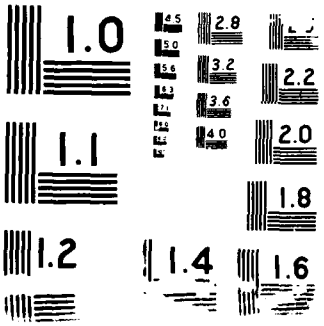
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Navy Personnel Research and Development Center

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Evaluation of Assignment Policies Using Optimization Models

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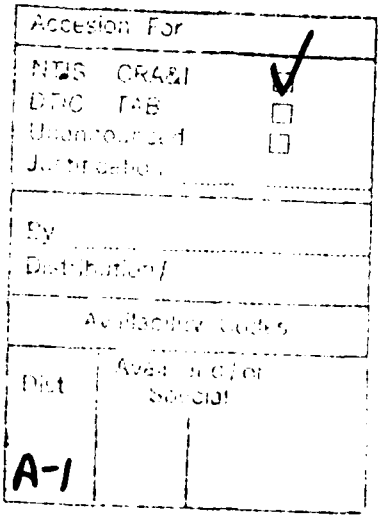

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This research demonstrates the capability of an assignment optimization model (EPANS) as a policy evaluation tool. EPANS enables Navy decision makers to quantify policy trade-off and to estimate the effects of new or modified policies. Results typically showed that gains in one policy come at the expense of another policy. Also, policies often interact in unexpected ways.

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FOREWORD

This report was prepared as part of work unit Z1770-MP006 (Personnel Assignment Systems). The objective of this project is to develop computer-based models to improve the Navy's personnel assignment system. NPRDC is developing the Enlisted Personnel Allocation and Nomination System (EPANS) as an automated aid for personnel assignment. The objective of this report is to show EPANS' capability to quantify policy impacts and aid decision making.

This report is one of several resulting from this project. Previous reports describe development of an automated assignment model for Seaman, Fireman, and Airman apprentices (NPRDC TR 86-24), and for selected Admin/Deck/Supply ratings (NPRDC TR 87-11).

Results of this report should be of interest to enlisted detailers and managers at the Naval Military Personnel Command (NMPC).

We thank LCDR R. Harris (NMPC-40BB) and MMCM T.L. Miller (NMPC-402C) for improvements to this report.

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SUMMARY

Problem

It is difficult for the Navy to estimate the impact of changes in assignment policy before those changes are actually made. Also, the Navy has no way to quantify the relationships among assignment policies. Since personnel assignment policies affect many aspects of naval operations, assignment policies should be given a thorough analysis prior to promulgation.

Objective

The objective of this research is to demonstrate the capability of an optimal assignment model (called EPANS) as a policy evaluation tool. EPANS enables Navy decision makers to quantify policy tradeoffs and to estimate the effects of new or modified policies.

Approach

The EPANS model was used to make assignments in six ratings: EM, MM, QM, RM, SH, and SK. The data for those ratings include personnel available for assignment, job openings (requisitions), and specialized training available (C-school). The EPANS model was run for each of the ratings and for several policy scenarios.

Results

Results typically showed that gains in one policy come at the expense of another policy. Also, policies often interact in unexpected ways. Ordering the importance of policies is necessary in EPANS to handle the multiple policies. Changing policy order between, for example, the number one and the number two policy also brings about changes for the number four policy, even though the number four policy retains its position in both order orderings. Some policies conflicted with each other in all our examples. Optimizing requisition priority always cost the most PCS dollars and optimizing NEC skill utilization always produced the fewest enroute training assignments.

Relaxing eligibility rules can improve results for other policies. For example, by allowing paygrade substitution between E-5 and E-6, NEC skill utilization was increased and PCS costs were reduced in our sample data. Conversely, adding new eligibility restrictions will degrade results for other policies.

Discussion

EPANS was developed to assist detailers in the assignment decision process. This model can also provide insights into many policy issues. It can be used to investigate the effects of new policies before the policies are actually instituted. EPANS can also be used to look at effects of various policy orders and of eligibility rules on assignments.

The usefulness of EPANS as a policy evaluation tool assumes its implementation and operational use.

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INTRODUCTION

Background

The Navy has numerous rules, regulations, and policies governing the assignment of its 500,000 enlisted personnel. Assignment decision makers (detailers) attempt to satisfy Navy needs, satisfy individuals' location preferences, control Permanent-Change-of-Station (PCS) costs, and satisfy several other assignment policies. As they make assignments, detailers must not violate a complex set of eligibility rules. They must also stay within aggregate resource allocation plans. The requirement for sea/shore rotation leads to a large volume of assignments every month, each of which must satisfy these multiple assignment policies.

Detailers assign personnel manually. Due to the large volume of assignments, they do not have the time to consider all possible combinations of person/job matches to find the optimal solution from a policy standpoint. Therefore, it is impossible to consider alternative policy standpoints and compare results. Assignment managers can only consider exceptions to policy on an individual basis without any information on global implications.

The optimal assignment models that constitute the Enlisted Personnel Allocation and Nomination System (EPANS) were developed (Liang, 1984 and Liang & Thompson, 1987) to optimize person/job matches. These models are useful as an operational tool, but also can be used as decision aids for evaluating and initiating policy.

Problem

It is difficult for the Navy to estimate the impact of assignment policy changes before changes are actually made. Also, the Navy has no quantitative way to determine the relationships among assignment policies. Since personnel assignment policies affect many facets of naval operations, assignment policies should be given a thorough analysis to determine effective decision alternatives.

Objective

The objective of this research is to demonstrate EPANS' capability as a policy evaluation tool. EPANS enables Navy decision makers to quantify policy tradeoffs and to estimate effects of new or modified policies.

APPROACH

Assignments were made and policy results summarized under various policy scenarios. This was accomplished using the EPANS model and data from six ratings: EM, MM, QM, RM, SH, and SK. The data include personnel available for assignment, job openings (requisitions), and specialized training available (C-school). The EPANS model was run for each of the ratings and for several policy scenarios. Results are compared among ratings and among policy scenarios.

EPANS Optimization Model

EPANS is a mathematical model which matches personnel to jobs in an optimal manner. Given a set of people, a set of jobs, and a set of training courses, the model is formulated through the following two steps. First, each person is compared to each job and it is determined if the person is eligible for the job and if the person is eligible for the job with appropriate training. Second, for every job a person is eligible for, a set of costs of assigning that person to that job are calculated. These costs include moving costs, job priorities, skill utilization, individual preferences, and fleet balance.

Once the model is formulated, this information is fed into an optimization program (Barr, Farhangian, & Kennington, 1986). This program provides an optimal match of people to jobs and enroute schools. This solution is optimal with respect to a preemptive policy order and the eligibility constraints. The policy order and eligibility rules can be modified by the user.

The basic concept of a preemptive approach to multiple policies is to optimize the policies one after another. The optimized value for the most important policy is found and then used as a constraint while finding the optimal value for the next policy. Both these values are then used as constraints and the third policy is optimized, etc. This method works very well for the Navy assignment problem.

Data Selection

Six ratings are presented in this report. They are: EM, MM, QM, RM, SH, and SK. Assignment models for these ratings have been developed and refined through numerous meetings with the respective detailers. However, none of these models is yet operational and results in this report must be interpreted with that in mind. The data used in this report is from August 1985 and includes PRD (projected rotation date) rollers, requisitions, and school quotas.

Table 1[1] contains the number of PRD rollers by rating and pay grade. The largest number of people are in paygrades 4, 5 and 6. Table 2 shows the number of PRD rollers by rating and PRD. The personnel were chosen to provide variety in the total number of people and in the total number of months for each rating. Table 3 contains the number of requisitions by rating and paygrade. In general there are many more requisitions than people to fill them. However, when paygrade, type of duty (sea or shore), special skills, and other qualifiers are considered there is often a shortage of appropriate job openings for particular personnel. Table 4 contains the number of requisitions by rating and take-up month. These months were chosen to correspond to the PRD's shown in Table 2. Detailers attempt to assign a person to a job that has a vacancy date later than or equal to the person's PRD. Tables 5 through 9 contain C-school quotas by Navy Enlisted Classification (NEC) for EM, MM, RM, SH, and SK respectively. There are no C-schools for QM.

[1] See tables at end of text.

Assignment Policies

The Navy has a variety of policies governing the assignment of enlisted personnel (See Table 10.). These policies may conflict with one another. Therefore, it is necessary to determine a priority sequence of policies before executing EPANS. Also, it may be desirable to exclude certain policies from time to time. EPANS has the capability of optimizing over any subset of the policies in any order specified by the user.

Eligibility Policies

Detailers must follow a complex set of rules and regulations when assigning personnel. These rules take the form of restrictions on what kind of personnel characteristics are allowed when filling a particular type of billet. A description of eligibility policy for EPANS is given by Liang, Thompson, and Zimmerman (1986). A few major eligibility policies are described here.

Type Duty The eligibility of PRD rollers for new assignment depends on their current duty and tour length. For instance, if a member is currently at sea duty and their PRD coincides with the end of their tour of sea duty, they would be eligible for shore duty. If the individual is far from completing their sea tour, they can be assigned to another sea duty job. There are exceptions. Sea duty eligible females and CT, MN, OT males can also be assigned overseas duty.

Paygrade Enlisted paygrades range from E-1 to E-9. Requisition paygrades range from E-3 to E-9. Usually E-1, E-2, E-3, and E-4 personnel are eligible for E-3 and E-4 requisitions. E-5 through E-9 personnel are eligible only for requisitions of the same paygrade. User input controls can override these rules.

PRD-TUM Window A person's projected rotation date (PRD) should be two months before, one month before, or equal to the job vacancy or "take up month" (TUM) date. This rule is also under user control.

NEC Restrictions If a requisition has a NEC requirement, a PRD roller is eligible if the NEC has already been earned, or if the person takes the appropriate training. Everyone is eligible for jobs that require an NEC earned through on-the-job training. Some NEC's are considered critical. Once a person has earned a critical NEC, they must be assigned to a job that requires that NEC.

RESULTS

This section contains examples of EPANS as a policy analysis tool. First, the model is run varying the preemptive ordering of policy goals. Second, the quantification of a single policy is varied and the effects on this policy and others is shown. Third, the results of relaxing an eligibility rule are shown.

Varying Assignment Policy Order

There are two general types of policy included in EPANS. Eligibility policies limit the jobs a person can potentially be assigned to. For example, females may not be assigned to combatant ships. Assignment policies provide

guidance as to what job a person should be assigned to, given a set of jobs he is eligible for. For example, assign requisitions with the highest priority first.

The version of EPANS used for this report contains fourteen assignment policies. The user may specify any ordering for these policies. If we want to examine all possible orderings, we would have to run the model over 80 billion times (14! = 14x13x...x1 = 87,178,291,200). This is clearly infeasible. Instead, we developed a "standard" policy order which is given in Table 10. We will concentrate on six of these policies, policies two through seven in Table 10. Policy one affects the assignment of females only. Sea duty eligible females are allowed to be assigned to overseas shore duty. Policy one says assign these females to sea duty, if possible, instead of overseas shore duty. Since the amount of females in our sample is so small (less than 5%) we do not examine this policy in detail.

EPANS was run six times for each rating. Each time one of the six policies was moved to position two in the preemptive ordering and the other policies retained their relative positions. Results are summarized in Tables 11 through 16 for EM, MM, QM, RM, SH, and SK respectively.

The data in Table 11 is interpreted as follows. When NEC utilization was the top policy, four people were assigned to jobs that required their NEC. Nineteen people had an NEC. The average PCS cost was $1720. Two of thirty CNO priority requisitions were filled. The average requisition priority was 36.1. Requisition priority values range from 1 to 999. Number 1 is the highest priority, therefore smaller values of average requisition priority are better. Thirty-nine percent of the people were assigned to one of their three choices or had no location preference specified. Nine people were assigned to class enroute to their job.

The values along the diagonal, upper left to lower right in Table 11, are the best attainable for each of the six policies. That is, matching 4 of 19 people with NECs to a job that requires their NEC is the best you can do with this data set. $1695 is the lowest average PCS cost attainable. Filling 5 of 30 CNO priority requisitions is the best attainable, etc. Of course these best values are not simultaneously possible. Instead, each is at the expense of the other policies.

Additionally, in Table 11, we see that when requisition priority is the first policy the average PCS cost is $3337. When minimizing PCS cost is the first policy, average PSC cost is $1720. Filling jobs in requisition priority order almost doubles PCS cost for these assignments. In Table 12 note the tradeoffs between NEC utilization and filling school quotas. If NEC skill utilization is the first policy, 25 people (of 42 with NECs) can be matched to jobs that require their NEC. When filling school seats is the top policy, 58 people can be assigned to school in route to valid job openings; but only two people with NECs are assigned to jobs that require their NEC. Another interesting policy result is shown in Table 14. No matter what the policy order nine and only nine CNO priority jobs can be filled. In summary, optimizing requisition priority always cost the most PCS dollars and optimizing NEC skill utilization always produced the fewest enroute training assignments.

Relaxing Eligibility

As mentioned earlier, eligibility rules take the form of restrictions on what kind of personnel characteristics are allowed when filling a particular type of billet. For example, females are not allowed on combatant ships; only U.S. citizens are allowed on nuclear powered ships; people with four or more dependents are not eligible for accompanied overseas duty. Presented in this section are examples of using EPANS to analyze paygrade substitution eligibility rules.

We will analyze assignment policy using paygrades E5 and E6 only. Usually, personnel at paygrade E5 are only eligible for E5 billets, and personnel at paygrade E6 are only eligible for E6 billets. We ran EPANS and summarized policy results under the following three scenarios: (1) no paygrade substitution, (2) allow E5 to E6, and (3) allow both E5 to E6 and E-6 to E-5. Policy order was the same for all runs and is given in Table 10.

Results are in Table 17 for the EM rating. Table 17 is interpreted as follows. The first line contains policy results with no paygrade substitution allowed. Three of nine people with NECs were assigned to jobs that required their NEC. The average PCS cost is $1678. Thirty-six percent of individual location preferences were met. The second line of the table shows policy results when we allow upward paygrade substitution only. That is, E5 personnel are allowed to be assigned to E6 jobs. In this case five of the nine people with NECs were assigned to jobs that required their NEC. Average PCS cost was reduced to $1629 and 39% of individual preferences were matched. This was accomplished while allowing only three E5 personnel to be assigned to E6 jobs. The third line shows policy results with both up and down paygrade substitution allowed. Now seven of the nine people with NECs were assigned to jobs requiring their NEC. PCS is further reduced to $1159 and 39% of individual location preferences were matched. However, we had to assign five E5 people to E6 jobs and twelve E6 people to E5 jobs. Additional results are in Tables 18 and 19 for MM and QM ratings.

DISCUSSION

EPANS was developed to assist detailers in the assignment decision process. This model can also provide insights into many policy issues. Policy makers can use EPANS to investigate the effects of new policies before the policies are actually instituted. Assignment decision makers can also use EPANS to look at effects of various policy orders and of eligibility rules on assignments before making the assignments.

Results for a single policy can be improved by moving that policy higher in the preemptive order and by relaxing eligibility rules. Improvements in achieving one policy goal are always at the expense of another policy. Adding or changing policies can produce unexpected tradeoffs with existing policies. For example, when we allowed paygrade substitution in the MM data, the number of location preferences that could be satisfied was not increased but was reduced. See Table 18. However, unlike the current situation, EPANS can be used to look at policy tradeoffs before policy decisions are implemented.

Table 1

PRD Rollers by Rating and Pay Grade

	Pay Grade									
Rating	1	2	3	4	5	6	7	8	9	All
Electrician's Mate	-	-	6	19	17	25	9	2	3	81
Machinist's Mate	1	-	7	17	36	33	5	2	2	103
Quartermaster	-	-	3	9	45	12	9	3	2	83
Radioman	2	2	8	15	33	52	14	3	3	132
Ship's Serviceman	-	1	2	22	41	29	13	2	1	111
Storekeeper	-	3	10	17	79	74	23	2	3	211

Table 2

PRD Rollers by Rating and PRD

	PRD							
Electrician's Mate	8508	8509	8510	8511	8512	8601	8602	All
Electrician's Mate	-	-	30	51	-	-	-	81
Machinist's Mate	-	-	23	80	-	-	-	103
Quartermaster	4	6	6	22	29	11	5	83
Radioman	-	-	43	89	-	-	-	132
Ship's Serviceman	-	6	9	54	42	-	-	111
Storekeeper	-	-	51	90	70	-	-	211

Table 3

Requisitions by Rating and Pay Grade

	Pay Grade							
Rating	3	4	5	6	7	8	9	All
Electrician's Mate	101	175	117	87	53	23	4	560
Machinist's Mate	85	174	197	155	50	13	7	681
Quartermaster	39	68	139	40	53	13	7	359
Radioman	84	194	207	65	93	18	7	668
Ship's Serviceman	144	142	112	87	19	12	5	521
Storekeeper	25	81	220	126	69	19	8	548

Table 4

Requisitions by Rating and Take-up Month

Rating	Take-up Month								
	8507	8508	8509	8510	8511	8512	8601	8602	All
Electrician's Mate	-	-	-	130	142	133	155	-	560
Machinist's Mate	-	-	-	123	163	160	235	-	681
Quartermaster	77	21	44	29	55	28	49	56	359
Radioman	-	-	-	156	91	145	276	-	668
Ship's Serviceman	-	-	48	74	82	61	129	127	521
Storekeeper	-	-	-	90	59	46	141	212	548

Table 5

"C" School Quotas by NEC
Rating = Electrician's Mate

NEC	Quota
4615	31
4626	5
4666	11
4668	30
4669	6
4671	42
4672	2
4673	4
Total	131

Table 6

"C" School Quotas by NEC
Rating = Machinist's Mate

NEC	Quota
4204	56
4245	59
4246	63
4252	88
4262	43
4291	30
4294	116
4295	60
Total	515

Table 7

"C" School Quotas by NEC
Rating = Radioman

NEC	Quota
2304	120
2313	52
2318	83
2342	62
2346	67
2355	8
Total	392

Table 8

"C" School Quotas by NEC
Rating = Ship's Serviceman

NEC	Quota
3111	20
3112	74
3113	85
3122	196
3154	60
Total	435

Table 9

"C" School Quotas by NEC
Rating = Storekeeper

NEC	Quota
2815	54
2817	94
Total	148

Table 10

Assignment Policies

1.	Assign sea duty eligible females to sea duty before overseas duty.
2.	Assign personnel with NECs to jobs that require that NEC.
3.	Minimize moving cost.
4.	Fill CNO priority jobs first.
5.	Fill requisitions in priority order.
6.	Satisfy individual location preference.
7.	Fill school quotas.
8.	Allocation.
9.	Minimize difference between personnel availability date and job vacancy date.
10.	Match person pay grade to job pay grade.
11.	Fill schools with earlier convening dates first.
12.	Minimize difference between personnel availability date and class convening date and between class graduation date and job vacancy date.
13.	Fill jobs with earleir vacancy dates first.
14.	Assign personnel with earlier PRDs first.

Table 11

Policy Results Using Six Different Policy Orders
for the Electrician's Mate Rating

	Policy Results					
First Policy	NEC Utilization	PCS Cost	CNO Pri	Req Pri	Loc Pref %	School Assign
NEC utilization	4/19	$1720	2/30	36.1	39	9
PCS cost	3/19	1696	2/30	36.1	39	10
CNO priority	4/19	2749	5/30	36.9	39	13
Requisition priority	2/19	3337	4/30	17.5	31	22
Indiv location pref	2/19	2223	3/30	39.4	56	11
Fill school quotas	1/19	2007	3/30	45.8	36	43

Note. Rollers = 81, Requisitions = 560, Schools = 18 (111 seats), Assignments = 70.

Table 12

Policy Results Using Six Different Policy Orders for the Machinist's Mate Rating

First Policy	Policy Results					
	NEC Utilization	PCS Cost	CNO Pri	Req Pri	Loc Pref %	School Assign
NEC utilization	25/42	$1011	3/36	63.1	56	19
PCS cost	17/42	778	2/36	63.9	53	24
CO priority	25/42	1597	5/36	59.8	54	23
Requisition priority	19/42	2864	5/36	30.7	52	36
Indiv location pref	23/42	1441	2/36	60.1	72	20
Fill school quotas	2/42	1146	4/36	61.9	52	58

Note. Rollers = 103, Requisitions = 681, Schools = 67 (339 seats), Assignments = 95.

Table 13

Policy Results Using Four Different Policy Orders for the Quartermaster Rating

First Policy	Policy Results			
	PCS Cost	CNO Pri	Req Pri	Loc Pref %
PCS cost	$2324	2/24	17.1	55
CNO priority	2388	3/24	17.1	55
Requisition priority	3324	2/24	15.6	54
Indiv location pref	2572	2/24	17.4	66

Note. Rollers = 83, Requisitions = 359, Assignments = 74.

Table 14

Policy Results Using Six Different Policy Orders for the Radioman Rating

First Policy	Policy Results					
	NEC Utilization	PCS Cost	CNO Pri	Req Pri	Loc Pref %	School Assign
NEC utilization	47/79	$3395	9/17	33.5	30	33
PCS cost	39/79	3254	9/17	32.6	34	39
CNO priority	47/79	3395	9/17	33.5	30	33
Requisition priority	40/79	4953	9/17	20.7	27	38
Indiv location pref	42/79	3925	9/17	34.2	51	36
Fill school quotas	33/79	3556	9/17	34.5	31	66

Note. Rollers = 132, Requisitions = 668, Schools = 39 (273 seats), Assignments = 106.

Table 15

Policy Results Using Six Different Policy Orders for the Ship's Serviceman Rating

First Policy	Policy Results					
	NEC Utilization	PCS Cost	CNO Pri	Req Pri	Loc Pref %	School Assign
NEC utilization	49/76	$2792	4/10	22.3	45	37
PCS cost	42/76	2690	3/10	22.1	45	40
CNO priority	48/76	2973	7/10	23.7	45	36
Requisition priority	43/76	4183	4/10	13.2	44	40
Indiv location pref	47/76	3201	4/10	22.3	61	38
Fill school quotas	10/76	3781	4/10	23.0	46	76

Note. Rollers = 111, Requisitions = 521, Schools = 45 (435 seats), Assignments = 101.

Table 16

Policy Results Using Six Different Policy Orders for the Storekeeper Rating

First Policy	Policy Results					
	NEC Utilization	PCS Cost	CNO Pri	Req Pri	Loc Pref %	School Assign
NEC utilization	33/63	$3658	11/33	36.0	48	56
PCS cost	26/63	3553	9/33	36.0	47	56
CNO priority	33/63	4336	24/33	33.5	46	59
Requisition priority	33/63	4823	14/33	26.7	44	53
Indiv location pref	31/63	4373	13/33	35.9	67	55
Fill school quotas	29/63	4426	11/33	37.7	48	110

Note. Rollers = 211, Requisitions = 548, Schools = 9 (148 seats), Assignments = 195.

Table 17

Policy Results With and Without Pay Grade Substitution for the Electrician's Mate Rating, Pay Grade E-5 and E-6 Only

Allowed Substitutions	Pay Grade Subs		Policy Results					
	5 to 6	6 to 5	NEC Util.	PCS Cost	CNO Pri	Req Pri	Loc Pref %	School Assign
None	0	0	3/9	$1678	1/20	27.9	36	4
Up only	3	0	5/9	1629	2/20	31.0	39	5
Up and down	5	12	7/9	1159	2/20	31.0	39	3

Note. Rollers = 36, Requisitions = 204, Schools = 18 (111 seats), Assignments = 36.

Table 18

Policy Results With and Without Pay Grade Substitution for the Machinist's Mate Rating, Pay Grade E-5 and E-6 Only

Allowed Substitutions	Policy Results: Pay Grade Subs 5 to 6	Pay Grade Subs 6 to 5	NEC Util.	PCS Cost	CNO Pri	Req Pri	Loc Pref %	School Assign
None	0	0	22/34	$ 858	3/21	56.9	56	10
Up only	8	0	24/34	877	5/21	50.8	53	11
Up and down	12	13	26/34	795	4/21	50.9	53	6

Note. Rollers = 66, Requisitions = 352, Schools = 67 (515 seats), Assignments = 66.

Table 19

Policy Results With and Without Pay Grade Substitution for the Quartermaster Rating, Pay Grade E-5 and E-6 Only

Allowed Substitutions	Policy Results: Pay Grade SubS 5 to 6	Pay Grade SubS 6 to 5	PCS Cost	CNO Pri	Req Pri	Loc Pref %
None	0	0	$1786	0/10	17.9	55
Up only	4	0	1628	0/10	17.7	51
Up and down	10	7	1573	0/10	17.6	55

Note. Rollers = 53, Requisitions = 179, Assignments = 53.

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